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OBSERVATIONS ON THE GERMINATION OF SPORES OF *PADINA TETRASTROMATICA* HAUCK

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ABSTRACT

The germination of the spores of *Padina tetrastromatica* Hauck from Mahabalipuram, South of Madras is described in detail for the first time from India for any member of the Dictyotaceae. The tetrasporangium, instead of forming the usual tetraspores, liberates its entire contents which germinate immediately on settling down on the thallus of *Padina tetrastromatica* Hauck. The liberated body is spherical in shape and on germination it produces at first a protuberance which on growing for some length as a tubular structure is cut off by a transverse wall from a spherical upper portion. The lower tubular portion, by a few divisions, forms a filamentous structure, the end cell of which produces a sort of a branched haptera on coming into contact with any foreign body. In the upper spherical portion cell divisions occur to result in a somewhat nodular structure. One of the superficial cells of this nodule grows out and by a transverse wall in this, an apical cell is cut off. By the activity of this apical cell new shoots of *Padina* are developed at first as cylindrical structures. By growth and division in all cells, later a flattened structure and then a fan shaped thallus is formed characteristic of the *Padina* plant. In the sequence of divisions and the formation of the rhizoid like structures, *Padina tetrastromatica* Hauck shows some differences from the other members of the Dictyotaceae reported earlier from abroad.

Padina tetrastromatica Hauck was observed by the author as one of the few Phaeophyceae that came up regularly during favourable seasons of the year at Mahabalipuram in the Chingleput District, South of Madras. The alga was met with in fair numbers in a small area enclosed by a Sea-groyne which was built up in front of a Shore-Temple at the coast. Here it was found growing attached to large boulders which were completely smothered by a thick sediment of very fine mud rendering the substratum almost slippery. During high tide the violent breakers dashing against the groyne wall constantly threw high up huge quantity of sea-water which as it fell inside the space enclosed by the groyne wall filled it up to form ultimately a sort of a temporary marine pool. The depth of water in some areas in this pool was found to reach 1.2 m. or even a little more, while in other places it was comparatively much less. Besides the breakers action in the formation of this pool, with the advancing tide the sea-water also rushed into this pool through small crevices and openings in the groyne wall. With the receding tide, however, the water from the pool flowed back into the sea and at periods of lowest tides, this pool got almost completely drained out except for a few very shallow depressions here and there with some accumulation of calm and clear water. In these situations *Padina tetrastromatica* Hauck was found in luxuriant growth being, however, subjected to repeated submergence and constant agitation during high tides followed by complete exposure and quiescence when tides were at the lowest.

During the cool months of the year, in January and February, plenty of fertile plants with tetrasporangia in definite zones characteristic of the alga were found. The old thalli of *Padina* were also found generally heavily loaded.with a number of epiphytes, the most common among them being Diatoms and species of *Ceramium* and *Heterosiphonia.* In addition, several young germlings of a few species of algae of the area were also noticed attached indiscriminately to the thallus. Some of the collections of *Padina tetrastromatica* Hauck were, however, found to be extremely interesting in that they showed in great abundance what looked like some delicate algae growing epiphytically on the thallus of *Padina* in regular concentric rows and along the zones where the sporangia were developed in *Padina.* These epiphytic structures were found to be further interesting in that the various individuals in particular rows were generally found to be more or less of the same stage of growth and development and those on the posterior and older parts of the thallus of *Padina* being more or less more advanced in their stage of development than those found on the relatively anterior portions. Individuals of the same row in different stages of growth and development were also not un-common in certain cases. In several cases, in the midst of these structures, empty sporangia could easily be detected. On a closer examination, these epiphytic structures were found to be really germlings of *Padina tetrastromatica* Hauck developed *in situ* on the germination of the entire sporangial contents (spore-mother-cells) immediately on liberation instead of their forming the normally expected tetraspores within the tetrasporangia. In some cases the germlings were seen attached indiscriminately to both the sides of the thallus of the *Padina* plant and they were either solitary or in small groups only.

Although the germination of tetraspores in some members of the Dictyotaceae has been described by Cohn (1865), Reinke (1878), Williams (1904), Carter (1927), Robinson (1932), Inoh (1936), Nishibayashi & Inoh (1959) and a few others, so far, there has however, been no record of germination of spores of any of the species from India. In the present paper, therefore, the observations made on one of the Indian species of *Padina* are described in some detail.

The tetrasporangia, when ripe, are very conspicuous, their contents being deep reddish brown in colour. They measure on an average between 65μ to 100μ across. Sooner or later, the entire contents of the sporangium is liberated as is evidenced by the presence of several empty sporangia in the midst of others intact. The liberated contents of the sporangium were seen settled down on the parent thallus itself. They were deep reddish brown in colour and more or less spherical to slightly ovoid in shape, each measuring about 65μ-100μ in diameter. They showed somewhat a highly gelatinised wall. No evidence of the sporangium dividing into tetraspores could be seen in the materials examined, and the liberated bodies from the sporangium thus correspond to the spore-mother-cells of the undivided tetrasporangium. Immediately after liberation, they begin to germinate and the earliest indications were seen in the contents of the spore becoming rather diffuse and yellowish brown with a tinge of green, and the spore-wall becoming highly gelatinised. Sooner or later, one portion of the spore grows out to form a small tubular protuberance (Figs. 1, 2 ; Pl. I., fig. 1). A portion of the contents of the spore migrates into this growth and the tip is found to be very rich in contents (Figs. 2, 3). This tubular structure grows further in length (Figs. 3-7 ; Pl. I., figs. 2, 3), and the tiny germinating spore gets itself somewhat firmly anchored in the gelatinised substrate obviously formed to a large measure by the dissolution of the old sporangial walls (Figs. 4, 7 ; Pl. I., fig. 2). In the next stage, a cross wall is formed higher up cutting off an upper spherical portion from a lower tubular portion (Figs. 6, 7 ; Pl. I., fig. 2). This is seen followed by a few transverse divisions in the lower tubular portion and repeated divisions in the same plane ultimately result in a more or less elongated filamentous structure (Fig. 8). Next, vertical walls are formed in some of the median cells of this filamentous structure (Figs. 8, 9, 10, 13, 15, 16) and this may be continued on throughout the filamentous structure in the later stages. The lowermost cell of this filamentous structure is filled with rich granular cytoplasm and when this cell comes into contact with any foreign body, it develops holdfasts (Figs. 11, 13, 14, 20, 21, 22, 23, 24, 25 ; Pl. I., fig. 6), and in extreme cases the holdfasts are seen as highly branched structures giving the germlings a firm anchorage (Figs. 14, 22, 25).

In the meanwhile, divisions occur in the upper enlarged portion of the developing spore. At first, it divides by a vertical wall (Fig. 10), and this is soon followed by another wall at right angles to the first, thus resulting in a quadrant stage (Fig. 11). Soon other divisions take place in different planes resulting in a multicellular spherical or oval structure (Figs. 12, 13, 14, 15, 16, 17 ; Pl. I, figs. 5-8). A similar structure resulting on the development of the tetraspore of *Padina pavonia* Lamour has been referred to by Carter (1927) as the *"central nodule"* of the new plant, and may in the present case be also referred to as such. In the next stage, one of the cells in the *"central nodule"* grows out as a small protuberance, and a transverse well in this protuberance cuts off an apical cell from a basal cell. This apical cell is easily distinguishable from the other cells of the *"central nodule"* by its richer contents and peculiar shape with a strong convex outer-face (Figs. 12, 14, 15). By further activity of this apical cell, and as a result of a series of divisions and growth of cells, ultimately a multicellular long and cylindrical structure is resulted, with a large apical cell anteriormost (Figs. 18-21, 23-26 ; Pl. I, figs. 6, 7). This new growth from the *"central nodule"* corresponds to the *"Rundtriebe"* of earlier observers (Reinke, 1878 ; Carter, 1927). As this structure grows further, it becomes more and more flattened (Fig. 27), and this stage is referable to the *"Flachtriebe"* of earlier reporters (Reinke, 1878 ; Carter, 1927). In favourable specimens, a single large apical cell could be detected in these structures also. By further growth and expansion of the juvenile thallus, ultimately a tiny fan-shaped young plant of *Padina* is formed, which is referred to as the *Breittriebe* stage in the development of the *Padina* plant. At this stage the single apical cell is seen replaced by a series of marginal cells.

As the germlings grow, certain cells developed unbranched multicellular hairs (Figs. 19, 20, 21, 25) and in the adult plant these hairs are seen in definite rows on the flattened fan-like thallus.

Generally, the apical cell formed in the *central nodule* lies in the longitudinal axis of the same, and at the pole just opposite to the filamentous structure ultimately developing the haptera. Though only one apical cell is formed from the *central nodule*, occasionally, however, there may be more than one formed with the result more than one *Rundtriebe* is developed from the *central nodule* (Figs. 24, 26). Occasionally, the apical cell instead of forming a *Rundtriebe* develops into a rhizoid, with the result two rhizoid like structures, each originating from opposite poles in the *central nodule*, are noticed (Fig. 16 ; Pl. I, Fig. 8).

In one case, however, instead of the entire enlarged portion of the germinating spore developing into a central nodule, only the lower half of it divided, while the upper half remained without any division. From this divided lower half, a new shoot was formed (Fig. 9).

Very frequently new shoots were also seen proliferating from the somewhat grown up germlings, resulting in a number of shoots originating from a common stock (Figs. 27, 29, 30).

The liberation of the entire sporangial contents without the spore-mother-cells forming tetraspores, and the subsequent germination of the liberated sporangia are not, however, quite unknown in Dictyotaceae. Reinke (1878) has recorded these phenomena in *Padina*, where the individuals do not produce any tetraspores. According to Williams (1904), in *Dictyota dichotoma* (Huds.) Lamour the undivided tetraspore mother-cells are sometime liberated without any evidence of karyokinesis and the mother-cells instead of forming tetraspores formed ultimately a parenchymatous body, in which an apical cell is formed which starts the growth of an elongated germling. The same phenomenon is reported for *Dictyota ciliata* J. Ag. also. Robinson (1932) observed in *Taonia atomaria* Ag. that the tetrasporangia without segmentation into tetraspores, had liberated the contents as a single spherical cell in some cases, and germlings developed out of these bodies in all stages of growth were noticed adhering to the surface of the mature plants. Nishibayashi & Inoh (1959) also observed in *Padina japonica* Yamada the liberation of tetraspore-mother-cells from the sporangia and their germination.

There would appear to be some difference as regards the sequence of divisions in the spore and the formation of the rhizoid-like structures as between *Padina tetrastromatica* Hauck now recorded and the earlier reports in Dictyotaceae. It is noticed that in most Dictyotaceae, the germinating spores first produce a multicellular body—*the central nodule*—and one of the cells of this nodule becomes protruded to form the apical cell of a cylindrical shoot, and the other surface cells giving rise to rhizoids. Thus in *Dictyota dichotoma* (Huds.) Lamour and *Dictyota ciliata* J. Ag., the mother-cell of the sporangium on germination forms first a parenchymatous nodule (Williams, 1904). According to Nishibayashi & Inoh (1959), in *Dictyota dichotoma* (Huds.) Lamour, and *Dictyopteris divaricata* (Okam.) Okam. the tetraspore first divides into two cells and from the lower of the two cells, by further divisions and protuberance a rhizoid is formed, while the upper cell starts the growth of the thallus. Williams (1898) reported that in the case of *Dictyota dichotoma* (Huds.) Lamour, when the unfertilised eggs germinated parthenogenitically, they underwent one or few divisions, and were only sometimes accompanied by the formation of rhizoid rudiments. In *Taonia atomaria* Ag. the tetraspore first segments by a transverse wall into two cells of equal sizes and one of it immediately forms a rhizoid like filament (Robinson, 1932). But in the case of spore-mother-cells, when they germinate, they divide irregularly to form a tubercle of 8 to 16 cells and the rhizoid originates from one or more of the peripheral cells at one pole of tubercle and the peripheral cells of the opposite pole gives rise to the thallus (*idem.* 1932). In *Padina pavonia* Lamour, the tetraspore first divides into two cells and further at right angles to the first division, which is followed by divisions in other planes, resulting in a central nodule. One or more of the superficial cells of this nodule give rise to filamentous rhizoids and one of the superficial cells becomes also the mother-cell of the young *Padina* plant (Carter, 1927). In *Padina japonica* Yamada, however, when the normal spore germinates, one end of the spore gives out a protuberance, and thereafter a transverse division cuts off a rhizoid filament (Nishibayashi & Inoh, 1959). In the case of spore-mother-cells in the same species simultaneous with the protrusions formed on germination, cell divisions occur to result in a nodule of 8 to 16 cells (*idem.* 1959).

In the present alga, however, when the spore-mother-cells germinate and develop, they produce at first a small protuberance, which under favourable conditions grows out into a long tubular structure, and a cross-wall ultimately separates this tubular structure from an upper spherical portion. Further divisions occur in the lower tubular filamentous structure before the upper spherical portion divides to form a nodular structure. Thus the filamentous structure is found to precede the formation of the nodular structure. Also the vertical wall formations seen in *Padina tetrastromatica* Hauck in the cells of the filamentous structure giving rise to the haptera do not appear to have been reported for any of the other members of the Dictyotaceae, although the illustrations given for *Padina japonica* Yamada (Nishibayashi & Inoh, 1959, figs, 4, 5), and *Taonia atomaria* Ag. (Robinson, 1932, fig. 8) would seem to suggest that such divisions do occur in other species as well.

According to Robinson (1932), the plants derived out of the unsegmented tetrasporangia in *Taonia atomaria* Ag. were of greater vigour, and he suggests that this means of reproduction may explain the predominance in nature of tetrasporic plants. According to Reinke (1878) the liberation of entire sporangial contents in *Padina pavonia* Lamour occurred in individuals that do not produce any tetraspores ; but in *Taonia atomaria* Ag. such conditions were encountered side by side with normal tetraspores (Robinson, 1932). In the light of these facts, it would be highly interesting to study the Indian species both cytologically and physiologically to understand the real significance of these perhaps not uncommon phenomena in Dictyotaceae.

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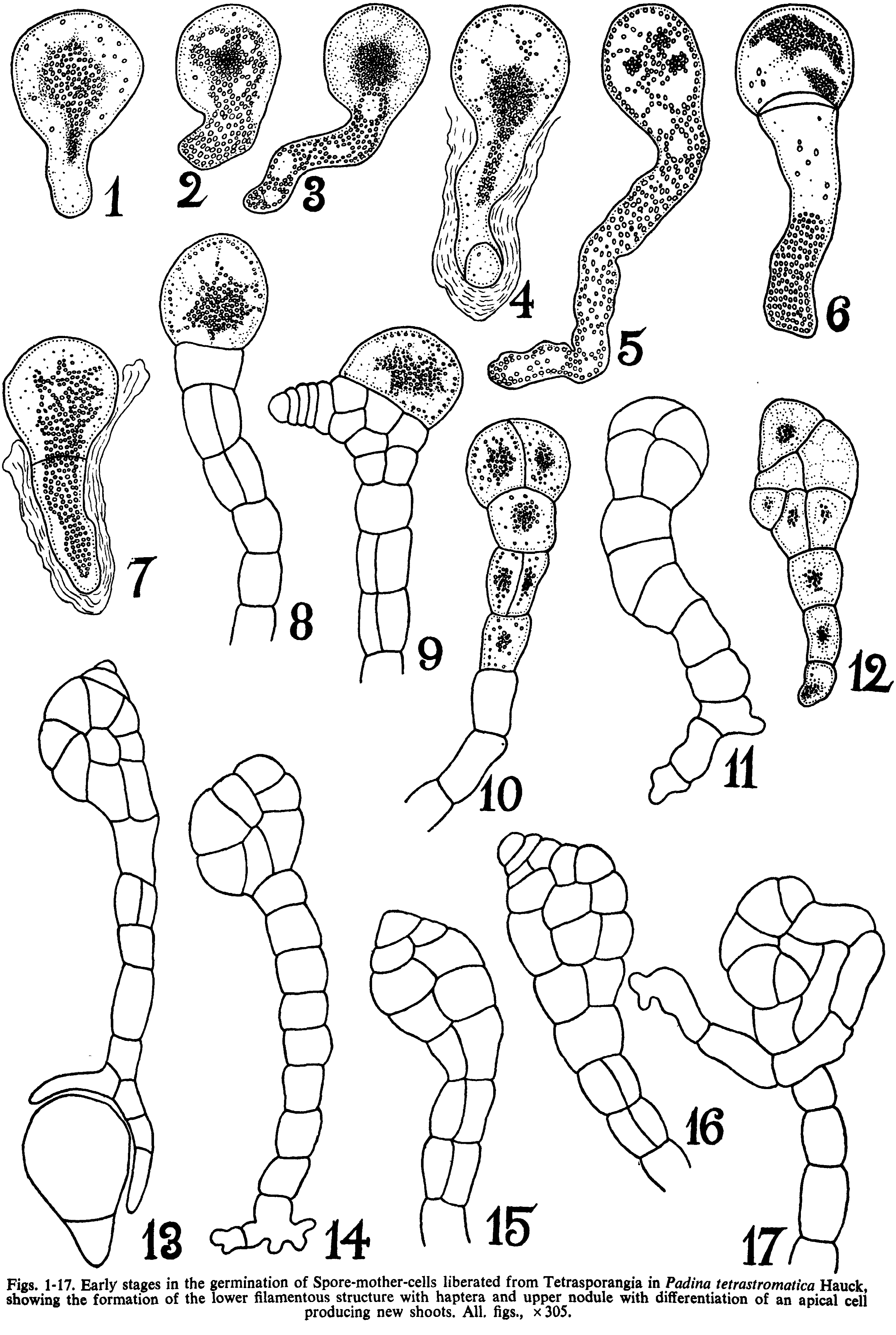
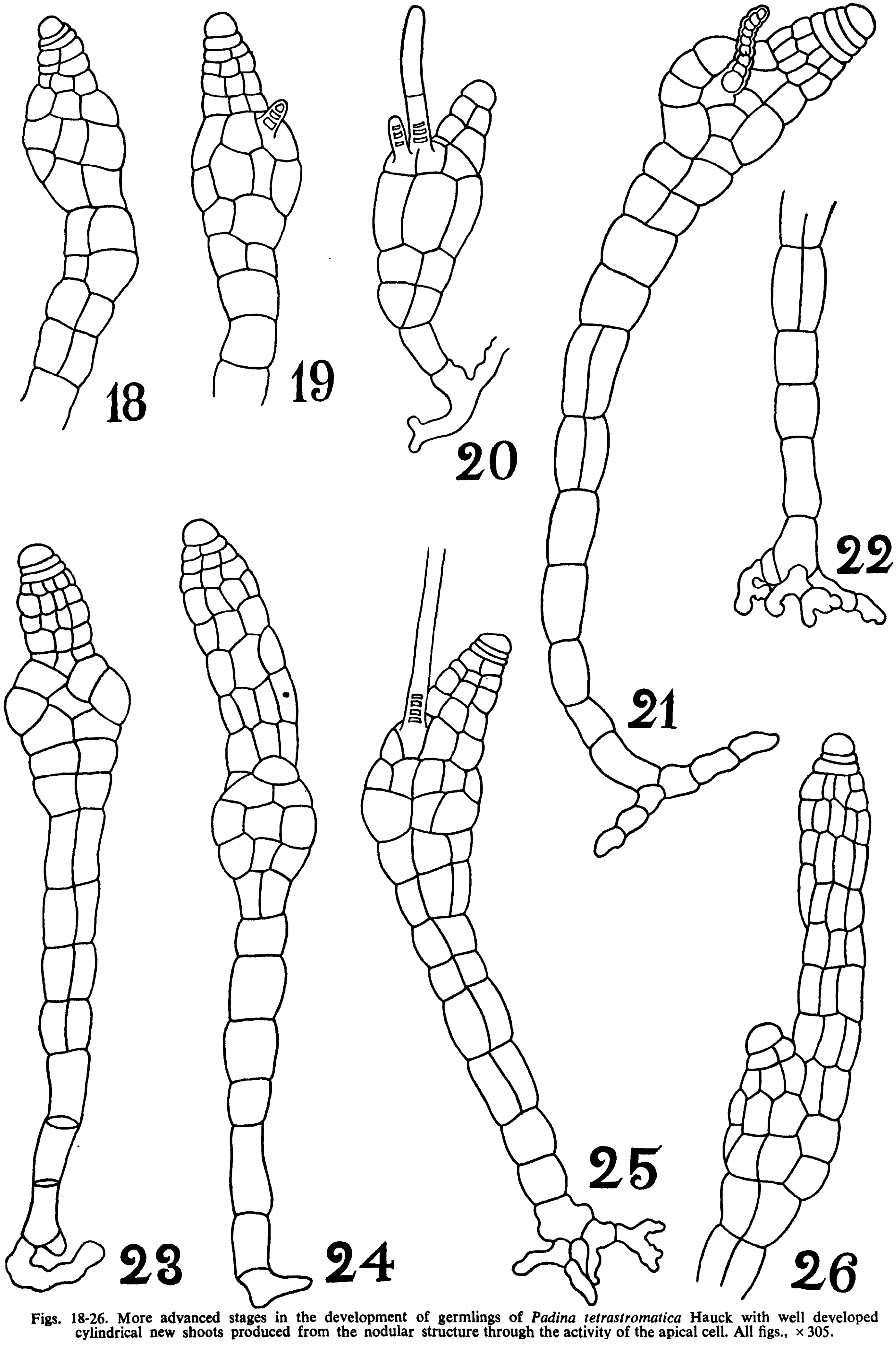
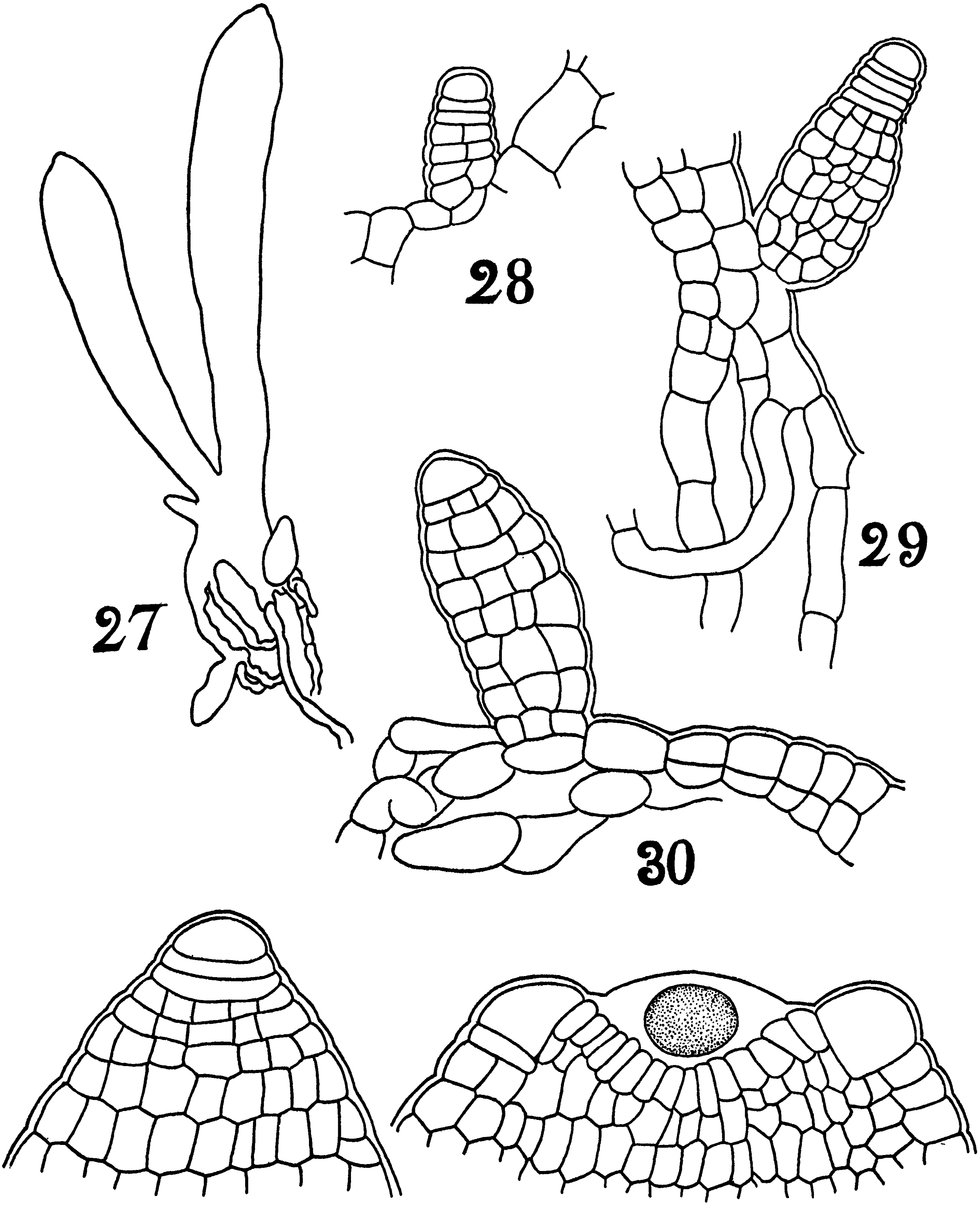


Figs. 1-17. Early stages in the germination of Spore-mother-cells liberated from Tetrasporangia in *Padina tetrastromatica* Hauck, showing the formation of the lower filamentous structure with haptera and upper nodule with differentiation of an apical cell producing new shoots. All. figs., × 305.



Figs. 18-26. More advanced stages in the development of germlings of *Padina tetrastromatica* Hauck with well developed cylindrical new shoots produced from the nodular structure through the activity of the apical cell. All figs., × 305.



Figs. 27-32. Still advanced stages in the development of juvenile plants with proliferating shoots from older portions and gradual replacement of the single apical cell of the shoots by a row of marginal cells in the adult plants. Figs. 27, × 72; 28-30, × 305; 31-32, × 576.

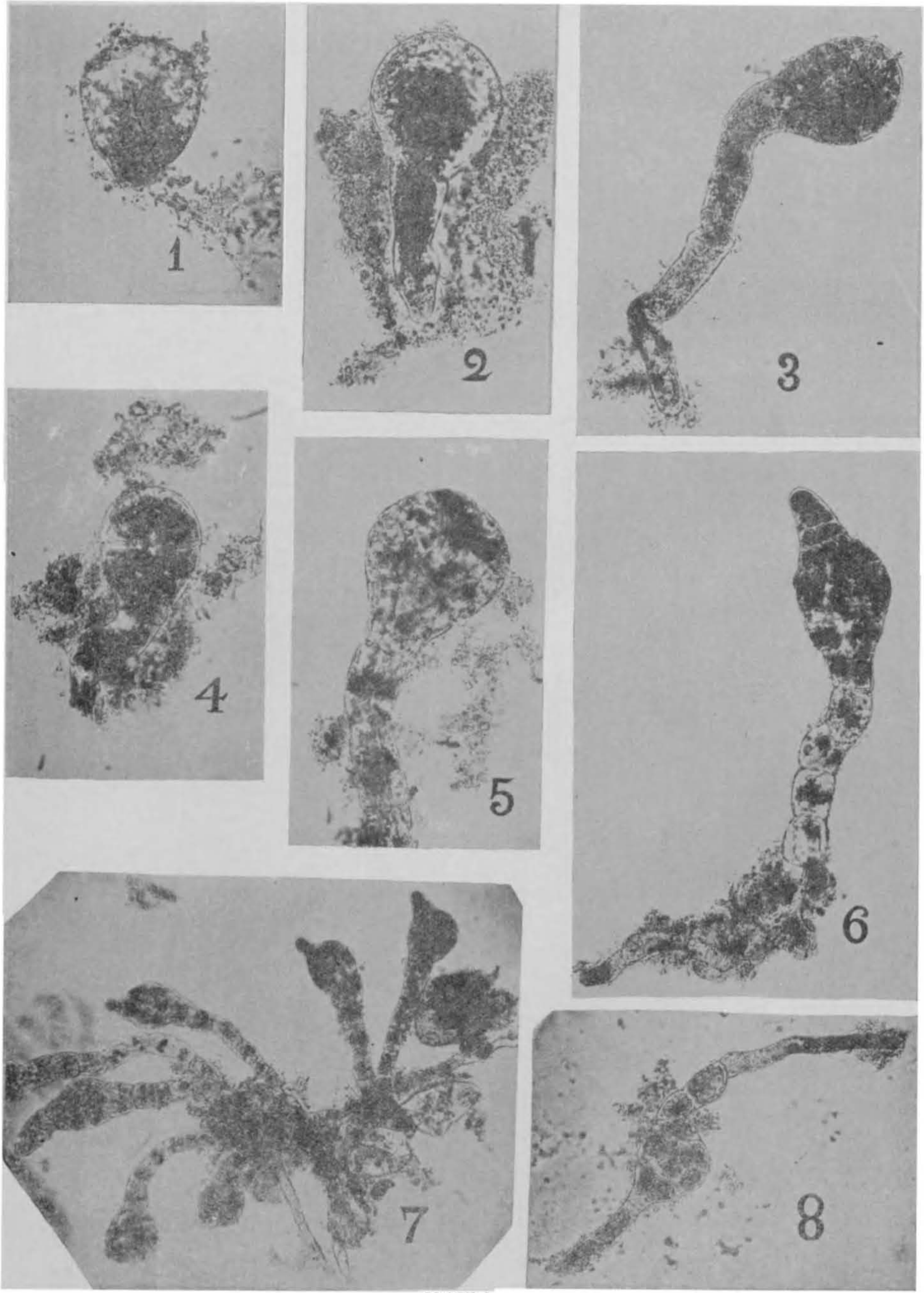


PLATE I

Figs. 1-8. Photomicrographs showing the various stages in the early development of Tetraspore-mother-cell of *Padina tetrastromatica* Hauck on liberation and germination.
Figs. 1, 3, 4, ×240; Figs. 2, 5, ×456; Fig. 6, ×180; Fig. 7, ×75; Fig. 8, ×120.